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Digitalization of Strategic Decision-Making in Manufacturing SMEs: A Quantitative SWOT-TOWS Analysis

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Abstract: The transition of contemporary manufacturing processes from digital to post-digital paradigms within the framework of Industry 5.0 necessitates the integration of both technological advancements and human-centered perspectives. This shift demands a high degree of customization and personalization in production processes, impacting both core and supporting operations. This study investigates the development of a software application designed to facilitate strategic goal-setting in manufacturing Small and Medium-sized Enterprises (SMEs) by leveraging a digitalized Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis. The research focuses on the use of this tool to collect, compare, and rank SWOT factors provided by employees and managers, in order to support data-driven strategic decision-making. The initial phase of the study involved a sample of 520 entrepreneurs and business owners from Poland, Slovakia, the Czech Republic, Hungary, and Serbia, which led to the identification of an extensive list of 83 strengths, 92 weaknesses, 78 opportunities, and 86 threats. These factors were stored in a Google Cloud Database, enabling subsequent comparisons with new data. A further 63 senior decision-makers tested the application by entering their own SWOT factors, comparing them with existing ones in the database, and ranking their significance for strategic planning. The rankings were calculated automatically, with the top-ranked factors forming the basis for further analysis. In the final stage, these rankings were reviewed by five experts from the research consortium, who conducted pairwise comparisons and employed Analytic Hierarchy Process (AHP) analysis to develop a Threats, Opportunities, Weaknesses, and Strengths (TOWS) matrix. This matrix identified potential strategic actions to optimize operations within the investigated region. The findings demonstrate the potential of the software tool to enhance strategic decision-making and improve organizational performance in manufacturing SMEs. The results offer practical insights for decision-makers seeking optimal strategies for operational optimization in their organizations.

Keywords: Digitalization; Strengths, Weaknesses, Opportunities, Threats (SWOT); Threats, Opportunities, Weaknesses, and Strengths (TOWS); Software application; Analytic Hierarchy Process (AHP); Manufacturing Small and Medium-sized Enterprises (SMEs)

1 Introduction

The optimization of industrial fabrication processes is a complex challenge that must be addressed at the strategic level and subsequently translated into operational decision-making. This optimization process involves difficult decisions related to technological investments, operating costs, work organization, and economic resources [1]. In such a complex environment, decision-making is inherently tied to Multi-Criteria Decision-Making (MCDA) processes, which typically require the support of contemporary MCDM methods and techniques. Industry 5.0, an emerging paradigm, builds upon the foundations of Industry 4.0. While Industry 4.0 is characterized by automation, digitalization, big data, and artificial intelligence, Industry 5.0 complements these with a focus on human-centricity, active collaboration between humans and machines, and decision-making grounded in human expertise [2]. The core of Industry 5.0 lies in the "humanization" of digitalized fabrication processes, a concept born from Industry 4.0. This humanization focuses on observing, measuring, collecting, and processing employees' opinions regarding all aspects

of their workplace environment. These insights are then used to develop strategic directions for further operational optimization. In this context, the input of employees at all organizational levels is crucial—ranging from operators to low-level, middle-level, and top-level management, as well as the owners of organizations, particularly within the SME sector. To effectively assess and process the vast volume of observations gathered from employees, this concept requires the development of appropriate digital tools capable of collecting and analyzing large datasets. Such tools should integrate well-established strategic planning frameworks, such as the SWOT or PASTEL matrix, with decision support techniques like AHP or ANP, and digital platforms for cloud-based data storage and processing.

SWOT analysis is one of the oldest and most widely adopted strategic tools globally [3]. Although it was developed many years ago [4], it continues to be widely applied in recent literature [5–7]. SWOT analysis is particularly prevalent in evaluating the strategic directions of SMEs. Dogan [8] noted that entrepreneurial culture relies heavily on the evaluation of strengths, weaknesses, opportunities, and threats—essentially, the foundation of SWOT analysis. Furthermore, SWOT analysis is frequently used to enhance entrepreneurship education [9, 10]. Despite its many advantages, SWOT analysis (or its variants, including the SWOT framework, matrix, model, technique, or tool) has faced some criticism within academic circles [3, 11–13]. Nevertheless, it remains widely accepted and is often upgraded or integrated with contemporary MCDM methods. For instance, Hayati et al. [7] combined SWOT analysis with MADM to prioritize potential strategies derived from the SWOT analysis. Similarly, Kafle et al. [14] employed the SWOT-AHP approach to assess the existing status of bamboo industries in Nepal. Yamagishi et al. [15] evaluated strategic marketing initiatives for small cooperative enterprises using SWOT-TOWS analysis, which was further assessed with PROMETHEE-GAIA. While such research demonstrates that integrating SWOT analysis with MCDM tools is not a novel approach, there remain areas for further refinement. Typically, SWOT analysis is conducted in the traditional manner, where a survey questionnaire is used to collect data, which is then processed by the facilitator. The resulting data is presented in a report outlining the identified SWOT elements. To quantify the SWOT factors, facilitators must run an additional round of analysis, where selected SWOT factors are included in a new survey and returned to decision-makers for rating. These ratings are then statistically analyzed to identify the most influential factors. Statistical analysis is often conducted using commercial software such as MS Excel or SPSS. Subsequently, the most influential SWOT factors are analyzed using MCDA techniques to determine potential strategic actions. The challenge with the procedures described in references [7, 14, 15] is that each stage of the analysis is performed separately, often manually. There is a noticeable absence of existing software applications that support quantitative SWOT analysis. While some commercial tools, such as the Miro template (https://miro.com/templates/swot-analysis/) or ClickUp (https://clickup.com), can be used for visualizing SWOT results, they lack the functionality to quantify and analyze SWOT factors. These tools primarily focus on visualization and do not facilitate the necessary quantification and further analysis through MCDA techniques. This highlights a clear research gap and underscores the need for the digitalization, automation, and quantitative analysis of SWOT.

Accordingly, to be able to deal with the observed research gap, the research presented in this paper deals with the digitalization of the strategic decision-making procedure, e.g., with the development of the software application that is used for conducting the SWOT analysis procedure in the organization, the evaluation and quantification of the obtained SWOT parameters, and the comparison of the obtained individual organization results with the average values generated and collected in the cloud database. Obtained outputs of the organizational SWOT parameters, collected by using this application tool, can further be used for strategic action planning, using the AHP for determining the priorities of the defined SWOT parameters, and forming the TOWS matrix for generating potential strategic directions. This will also be presented with adequate examples in the remainder of this manuscript.

The idea for this research was initiated during a previous investigation on the research project "How to prevent SMEs failure (Actions based on comparative analysis in Visegrad countries and Serbia)," which was financially supported by the International Visegrad Fund during 2018-2019 [16]. In the frame of this research project, entrepreneurs from industrial SMEs in Serbia and all four Visegrad countries (Poland, Slovakia, the Czech Republic, and Hungary) were asked to evaluate the most important factors in their SMEs' failure and potentially successful recovery. A sample of 520 responses was collected during the survey. Obtained results, presenting the profiles of analysed SMEs and respondents, and identifying the most important reasons for SMEs failure and the rate of recovery were published in the manuscripts [17, 18]. During the research on this project, the entrepreneurs were also asked to complete the SWOT analysis of their organizations. Obtained factors representing organizational strengths, weaknesses, opportunities, and threats were collected and stored in the Google Cloud database. As a result of this initial project, within the same consortium, with the addition of researchers from Bulgaria, another research project was prepared with the title "Possibilities and barriers for Industry 4.0 implementation in SMEs in V4 countries and Serbia." This project was realized in the period 2021-2022, again with the financial support of the International Visegrad Fund (https://mksm.sjm06.com/visegrad-project-2021/). The SWOT software application, which will be described in this manuscript, was developed as one of the activities of this project. Namely, in the frame of this research project, a new study was conducted in Serbia, Bulgaria, and the Visegrad four countries (V4 countries). The firms that were included in the study were in the dominant fields of production, among which many were at a high level of digitalization of their

industrial processes. Among them, several areas of business activities were selected: construction and development, mining and ore excavation, manufacturing, wholesale and retail trade, information and communication technologies, machinery and equipment, and the energy sector. During the research phase of the project, 635 respondents were surveyed from 63 different organizations. The respondents were in positions as owners, senior managers, managers, and employees of investigated organizations. Profiles of analysed firms and respondents included in the research are available in the study of Mihajlović et al. [19] and also in the study Mihajlović [20] and Milošević et al. [21]. Besides being interwoven on different aspects of the Industry 4.0 concept and digitalization level of their organizations, owners and top managers were also asked to test the SWOT software application developed during the project. The results of this testing will be presented in this manuscript.

2 Methodology

SWOT analysis is an effective tool for helping organizations understand their internal and external business environment by analysing their operations across four areas, namely strengths, weaknesses, opportunities, and threats, assisting with the formulation of strategic plans and decisions [13, 22, 23]. Strengths and weaknesses are the internal factors that support and hinder an organization from achieving its mission, respectively. Opportunities and threats, on the other hand, are external factors that enable or disable an organization to accomplish its mission, respectively [24].

The simplicity of conducting a SWOT analysis is its significant advantage [13]. By analysing the internal and external business environment (for example, by using the brainstorming method or a survey), a SWOT matrix is formed. Just using the SWOT analysis is enabling the decision maker to collect in one place identified strengths, weaknesses, opportunities, and threats.

This is usually not enough information to lead to determining the practical directions for organizational improvement. Accordingly, based on the SWOT matrix, four strategic combinations can be defined by pairing internal and external factors in the form of the TOWS matrix. This way, TOWS analysis involves creating strategic options by combining internal strengths and weaknesses with external opportunities and threats. This leads to four types of strategies: maxi-maxi (strengths/opportunities), maxi-mini (strengths/threats), mini-maxi (weaknesses/opportunities), and mini-mini (weaknesses/threats) [25, 26]. Finally, each combination of internal and external factors can be used to create and evaluate potential strategic options.

Having in mind the previously stated argument, the native SWOT analysis lacks a proper mechanism for evaluation, comparison, and rating of the obtained SWOT factors. Accordingly, the importance of each factor in decision-making cannot be measured quantitatively, making it difficult to assess which factor influences the strategic decision most, which is a significant limitation of the SWOT approach [27]. This way, it is often integrated with some MCDM tool to overcome this situation. In expanding the SWOT analysis with adequate tools for ranking optimal strategies, numerous decision-making methods have been suggested in the literature that broaden its application and create numerous opportunities for making objective decisions [28]. Among the most commonly used models of multicriteria decision-making, aimed at defining prioritization of strategies, is AHP [29–35]. The AHP method developed by Saaty [36] is flexible and enables decision-makers to assign relative importance to each factor through a pair-wise comparison [35]. Focus group participants compare factors within and between each category using a predetermined scale [36]. Accordingly, one possibility to expand the SWOT method is to combine SWOT with AHP. This way, integrated SWOT-AHP can provide a quantitative measure of the importance of each factor in decision-making [37]. In such integration, the AHP technique can estimate relative priorities for each factor of the SWOT matrix. The pairwise comparison implies that applying the SWOT-AHP method is preferable for small sample sizes of individuals or groups that are knowledgeable about the issue under investigation [37, 38].

The SWOT-AHP analysis is usually carried out in six subsequent steps. In the first step, internal and external factors are identified using the SWOT analysis. It is recommended not to use a large number of factors within SWOT groups (less than 10). In the second step, a hierarchical structure should be created that includes the SWOT factors at different levels. In the third stage, the SWOT groups are prioritized. Prioritization is done by pairwise comparisons between factors to determine their relative importance. This requires assigning the numerical values to represent the preference or importance of one factor over another. In the fourth stage, the consistency check is performed. This procedure should ensure the consistency of the pairwise comparisons through the calculation of consistency ratios. Sometimes the adjustments to the comparisons are necessary to improve consistency. In the final stage, the weight calculation is done by calculating the weights of the SWOT factors based on the pairwise comparison results. The weights represent the relative importance of each factor in the decision-making process [29, 39]. The best-ranked factors of all four SWOT groups can then be used to obtain adequate TOWS strategic alternatives.

Accordingly, SWOT is a technique precisely created to conduct competitive strategy analysis [40]. On the other hand, regardless of the long tradition of using this method, SWOT analysis, in its initial form, has some shortcomings, which were recently elaborated in detail by Wu et al. [13]. Traditionally, SWOT analysis is typically used manually in order to identify SWOT factors, which can potentially lead to subjective results [13, 41]. Also, if the SWOT analysis is used as the sole instrument without integration with some MCDA technique, the importance of the obtained SWOT

factors is rarely evaluated [42]. Also, SWOT analysis is usually a one-time event; thus, in its native form, it is without a proper mechanism to monitor changes throughout a long-term dynamic competitive situation [43]. Therefore, it has been suggested that SWOT analysis should be conducted from a dynamic perspective.

Having all this in mind, as well as the previously described research gap, this research has been focused on overcoming certain shortcomings of the SWOT technique through the automation and development of a software application that will enable decision-makers to conduct the SWOT analysis in their organization, including all employees, who will be able to express their opinion and propose potential organizational SWOT factors. Besides its feature to collect the organizational SWOT factors based on all employees' evaluation, the application will also enable the decision maker to compare the SWOT factors collected in his/her organization with an already stored list of previously collected ones and, based on this comparison, define the final list. Such a defined final list of selected SWOT factors is further subjected to individual rating by the decision-makers, still in the frame of the same software application. Such obtained ranking is then compared with the recorded list of average values of the SWOT factors, stored in the central database and offered to the decision maker for the further procedure of MCDA evaluation and subsequently transformed into an adequate TOWS matrix, which can be used to indicate the most important strategic action for the organizational improvement.

The entire process of SWOT factor collection and the procedure of their quantification is facilitated by using the graphical user interface (GUI) of the application. The GUI of the application, as well as the entire application, is programmed using the Python programming language. The entire code of the application is made publically available on GitHub at the following link: https://github.com/imihajlovicBor/SWOT. The GUI of the application is programmed using the tkinter, which is the standard Python interface to the Tcl/Tk GUI toolkit. Besides being used for the direct input of the decision-makers SWOT factors, the GUI also generates a link to the Google form that can be sent to an unlimited number of co-workers who can also enter the SWOT factors of the same organization. The Google form is available at: https://docs.google.com/forms/d/e/1FAIpQLScN1rNK_F89_E60x6uPCX2EVKG5MytARXHRePcZUzVoyQhPDA/viewform.

All entered SWOT factors are collected in the same database, which is located on the Google cloud, and collected data can be assessed by the decision-maker using the same GUI of the application. For simplicity of data collection and processing, the entire database is actually formed using Google-Docs spreadsheets. Namely, the SWOT factors collected using the Google forms are by default placed in the corresponding Google spreadsheet's first sheet. For this application, we integrated the GUI form, where the decision makers are entering their SWOT factors with additional Google spreadsheet sheets. Namely, the second sheet is used to collect strengths entered through the GUI, the third one for weaknesses, the fourth for opportunities, and the fifth for threats. The code used to connect the GUI form with the Google spreadsheet is as follows:

```
def get_entry_fields_S():
scope = ['https://spreadsheets.google.com/feeds','https://www.googleapis.com/auth/drive']
creds = ServiceAccountCredentials.from_json_keyfile_name('My Py Project-5043b4333ff3.json', scope)
client = gspread.authorize(creds)
sheet = client.open('SWOT Analysis (Responses)')
df1 = pd.DataFrame('SNAGE':[entry1.get(), entry2.get(), entry3.get(), entry4.get(), entry5.get()])
sheet_snage = sheet.get_worksheet(1)
sheet_snage.append_rows(df1.values.tolist())
```

To be able to make such integration json keyfile had to be created, using the predefined Google cloud procedure, described at: https://developers.google.com/workspace/guides/create-credentials. The same procedure is repeated for the weaknesses, opportunities and threats.

Considering that there is a chance that different employees enrolled in the survey can propose similar or the same SWOT parameters, the application enables the decision-maker to do the evaluation, combining the similarities and deleting the repeated factors from the database. This operation is briefly defined as filtering. The application offers the decision-maker the option to use only the list of SWOT parameters obtained from his/her organization or to integrate it with the list of SWOT parameters already stored in the database from other organizations included in the survey. In both options, the result of the filtering is a refined list of SWOT factors, with repeated lines (or items) eliminated. Such procedure was done using the integration of tkinter for GUI and Python's library Pandas, e.g., Pandas table, for creating the form that will be used to list and filter the SWOT parameters from predefined lists.

The application enables the decision-maker to perform a rating of the refined list of strengths, weaknesses, opportunities, and threats in a new GUI. The GUI for the rating contains a drop-down list of refined SWOT factors, which enables the decision-maker to select up to 5 most important elements and rate them on a scale from 1 to 10 (where 1 stands for the less important and 10 for the most important). This new GUI was also developed in the tkinter toolkit with the assistance of the Pandas library. The entire code that was created for this segment of the application is too large to be presented in the manuscript; however, it can be read on the GitHub link: https://github.com/imihajlovicBor/SWOT, in the "initial.py" file, in the segment "def wotting_GUI()".

After the rating is completed, the application enables storing the resulting list of rated factors in the central database located on the Google Cloud. This is also done in the same Google spreadsheet, in the form of additional sheets. A separate sheet is opened for rated values of strengths, weaknesses, opportunities, and threats.

Subsequently, the decision-maker can open the report, presenting his/her rating compared by the average scores of other decision-makers in the database. The code that enables the decision maker to collect ratings of the strengths can be read in the segment "def get_wotting_entry_S()" in the "initial.py" file of the https://github.com/imihajlovicBor/SWOT, while the code for getting the average values of all the ratings is available in the segment "def get_Rank()" of the same file. The same procedure is repeated for weaknesses, opportunities, and threats. This way, the application enables the decision-maker to compare the most important SWOT parameters of his/her organization with the overall ranking of importance of the SWOT parameters generated after evaluation by decision-makers in other organizations. Besides this sort of benchmarking purpose, the overall ranking of the SWOT parameters is the starting point for the creation of alternative strategic actions and their ranking in a hierarchical way using the AHP method. The explained methodology on which the application is designed is presented in Figure 1. Basically, the entire application is developed using the Python programming language, including the tkinter, pandas, gspread, oauth2client, openpyxl, and webbrowser libraries.

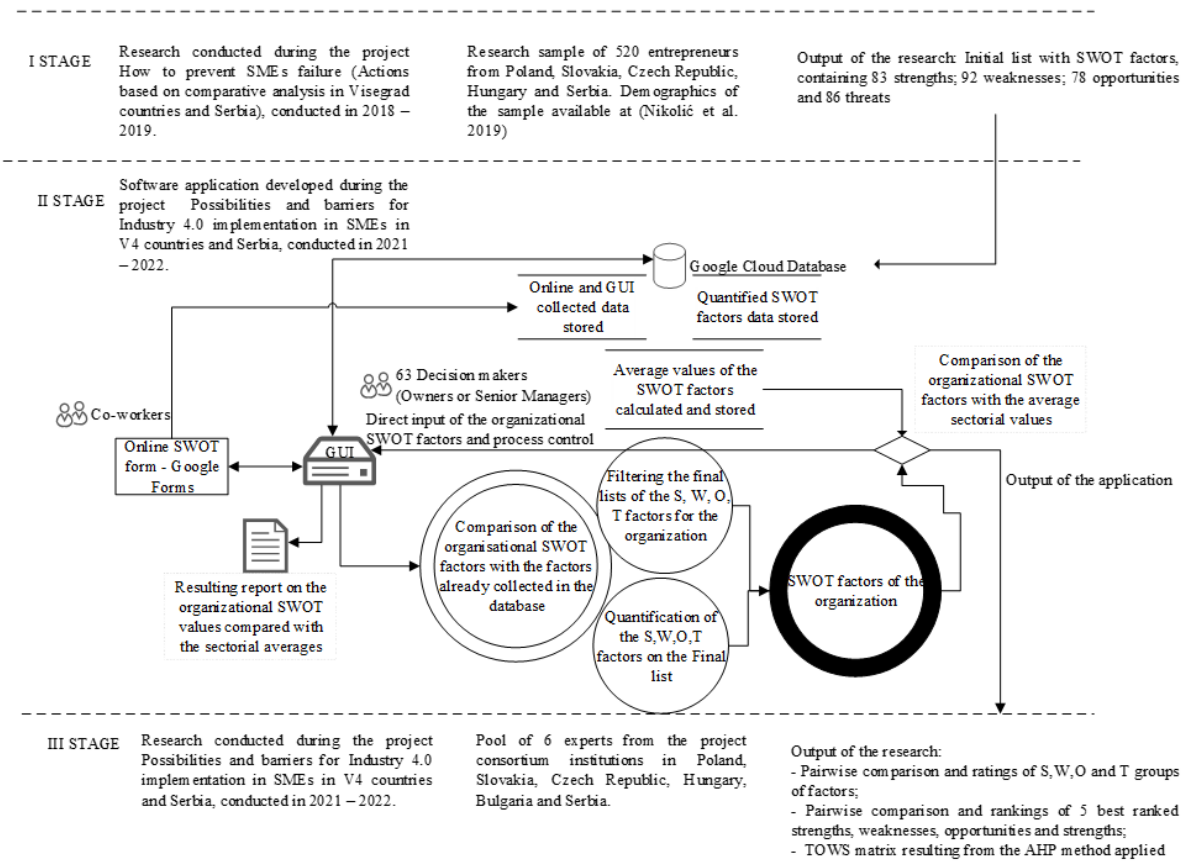

Figure 1. The methodological pattern of the SWOT application

Note: This figure was prepared by the authors.

3 Results and Discussion

During the research conducted on the project "How to prevent SMEs failure (Actions based on comparative analysis in Visegrad countries and Serbia)" [16], 520 entrepreneurs from all four V4 countries and Serbia, among other survey questions [17, 18], were asked to fill out the SWOT form of their organization. As a result, the researchers generated a list of over 100 unstructured SWOT factors. After the elimination of duplicates and grouping of similar responses, a final list with 83 strengths, 92 weaknesses, 78 opportunities, and 86 threats was created and stored on the Google cloud.

Subsequently, during the research on the project "Possibilities and barriers for Industry 4.0 implementation in SMEs in V4 countries and Serbia" [22], a software application was developed as a potential tool for the decision-making process dedicated to the selection of the optimal strategic directions for strengthening the position of the SMEs

operations. The application was developed using the Python programming language. When installed and executed, the application presents the graphical user interface (GUI), as shown in Figure 2.

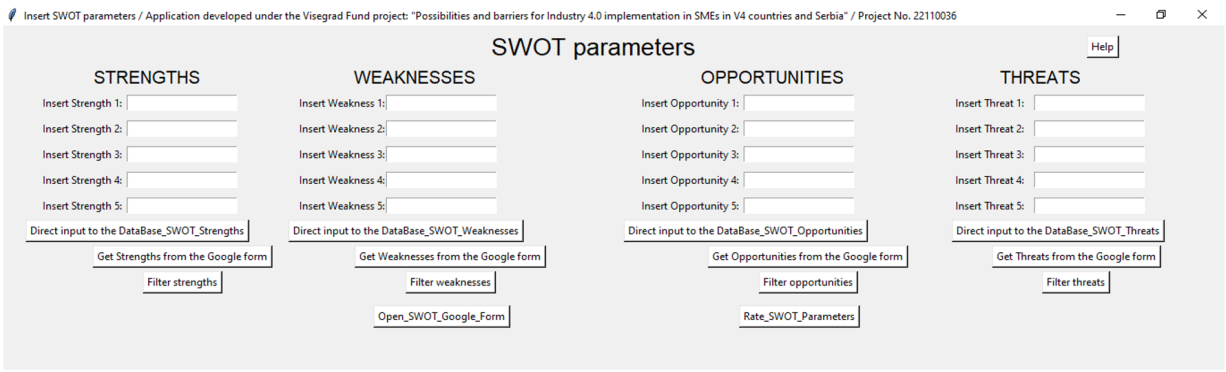

Figure 2. Initial graphical user interface of the SWOT application

Using the GUI, decision-makers can directly enter the SWOT factors of the organization. Also, the app enables the decision maker to open the Google form with the SWOT survey, which can be forwarded to other decision-makers, e.g., the co-workers of the decision maker. SWOT factors entered through the GUI and/or Google form are also stored in the central Google cloud database, as described in the previous section.

After the data acquisition, the decision maker can import the lists of stored Strengths, Weaknesses, Opportunities and Threats, using the button "Get Strengths from the Google Form", or the corresponding buttons for the W, O, and T lists. Subsequently, the decision-maker should proceed to the stage of S, W, O, and T filtering. Namely, using the button of the initial GUI, with the text "Filter strengths", a new extension of the GUI appears (Figure 3), which enables the decision maker to compare his/her factors with those already available in the database. The factors inserted by the decision-maker will always appear at the top of the list. This option is available because the decision-maker can sometimes avoid some important factors, so the available list can be treated as a form of reminder.

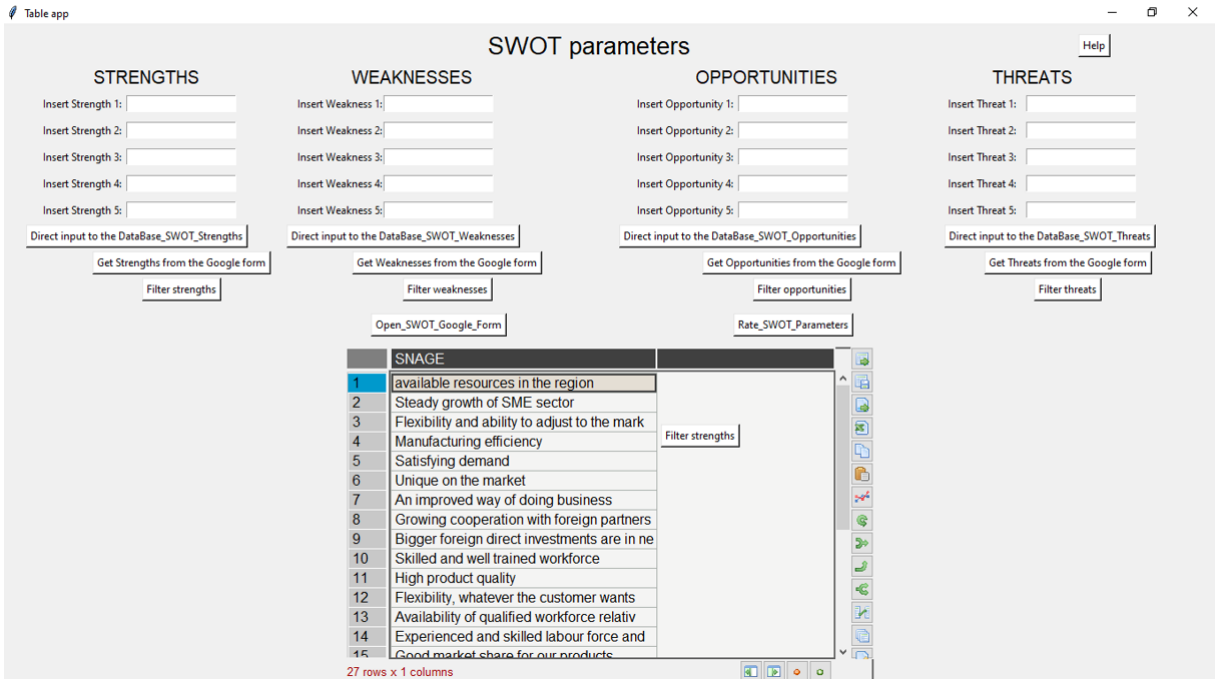

Figure 3. GUI that enables the decision maker to refine and generate final list of strengths

There is no limitation on the number of items that should remain on the final list of S, W, O, and T factors after the filtering stage; however, it is optimal to keep it at 20-30 items. The factors that remain on the list after the filtering will be submitted for quantitative ranking by the decision-makers. The ranking operation is executed by using the button "Rate SWOT Parameters." Using this button will open the next GUI (Figure 4).

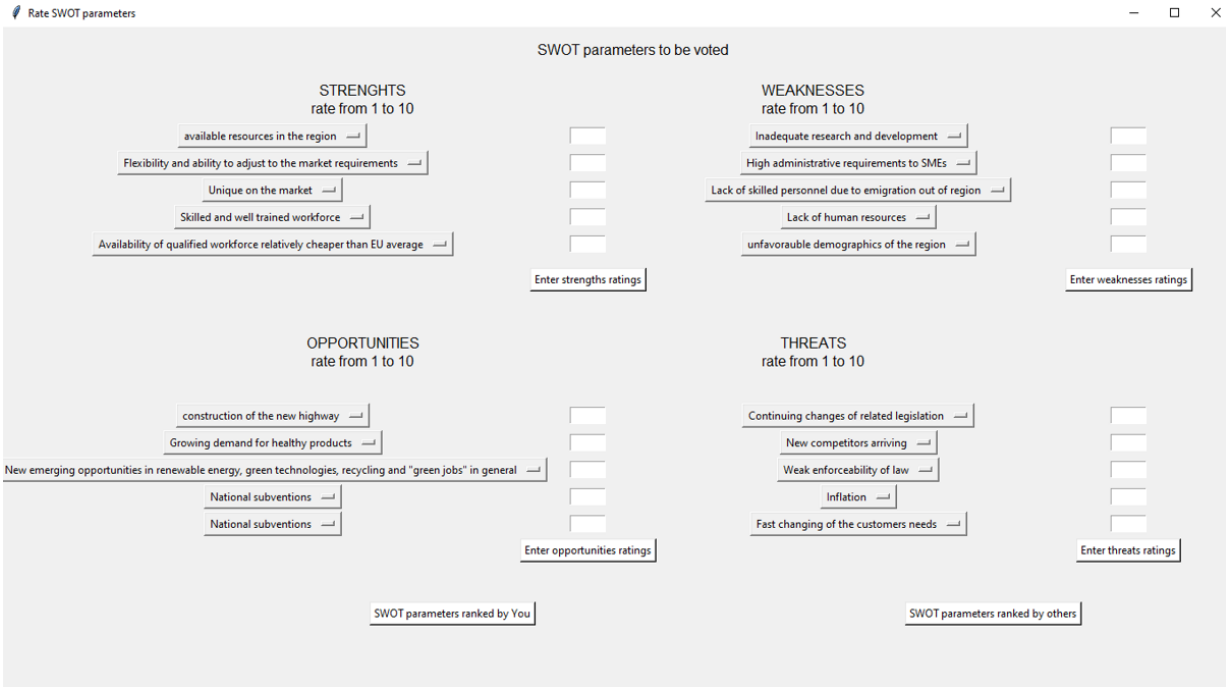

Figure 4. GUI that enables decision maker to rank the importance of SWOT factors

Ranking is organized using the drop-down lists for all S, W, O, and T factors on the resulting list generated in the previous operation. The decision-maker can rank the SWOT factors with grades from 1 (less important) to 10 (the most important). After the ratings, the final scores are stored in the central database of the application and compared with previously stored average values. This enables the decision-maker to compare his/her scores with the scores available in the database, generated as the average values of all ratings stored at that stage. Obtained results can serve as valuable tools for identifying internal strengths and weaknesses, as well as external opportunities and threats for SMEs. As pointed out by many organizations, they struggle with the subjective nature of SWOT analysis, often leading to biased assessments [13, 41]. This is the reason why, in the tool described in this paper, the decision-makers are also offered to compare their evaluations with the evaluations of other respondents collected during the previous surveys.

Table 1. Top five SWOT factors ranked by the decision makers

Strengths		**Weaknesses**	
Factor	Score	Factor	Score
S1 - adequate supply chain	7.50	W1 - insufficient financial resources for growth	9.10
S2 - availability of necessary raw materials	7.00	W2 - obsolete equipment	8.92
S3 - large foreign companies are looking for local subcontractors	6.71	W3 - high administrative requirements for SMEs	8.20
S4 - flexibility and ability to adapt to market needs	6.67	W4 - lack of capital and limited access to funds	7.50
S5 - stable growth of the SME sector	6.40	W5 - lack of human resources	7.00
Opportunities		**Threats**	
O1 - development of a new industrial zone in the region	9.23	T1 - increasing production costs	9.56
O2 - external support (support from the state and foreign investors)	8.87	T2 - lack of necessary resources	8.93
O3 - the end of the COVID pandemic	8.52	T3 - the coming recession that is just beginning	8.10
O4 - growing demand for healthy products	7.53	T4 - deteriorated natural conditions	7.23
O5 - EU programmes and funds for the development of the SME sector	7.12	T5-continuous changes in the legal framework of business	6.83

During the stage of pilot testing of the application, decision-makers (owners and top managers) of 63 organizations from V4 countries - Bulgaria and Serbia - were asked to perform the described operations. A matrix of average values of five top-ranked strengths, weaknesses, opportunities, and threats, generated by all decision-makers involved, is

presented in Table 1.

To be able to develop the strategic actions based on the decision-makers' ratings, the AHP procedure was applied. Based on the SWOT-AHP hybrid model for prioritizing strategic actions, on the basis of the results of the SWOT factors, sub-factors, defined strategies, and established goal of determining the best strategy, the AHP model, presented in Figure 5, was developed for defining the mutual relations between SWOT factors and sub-factors in order to prioritize defined strategies for the SMEs included in the research.

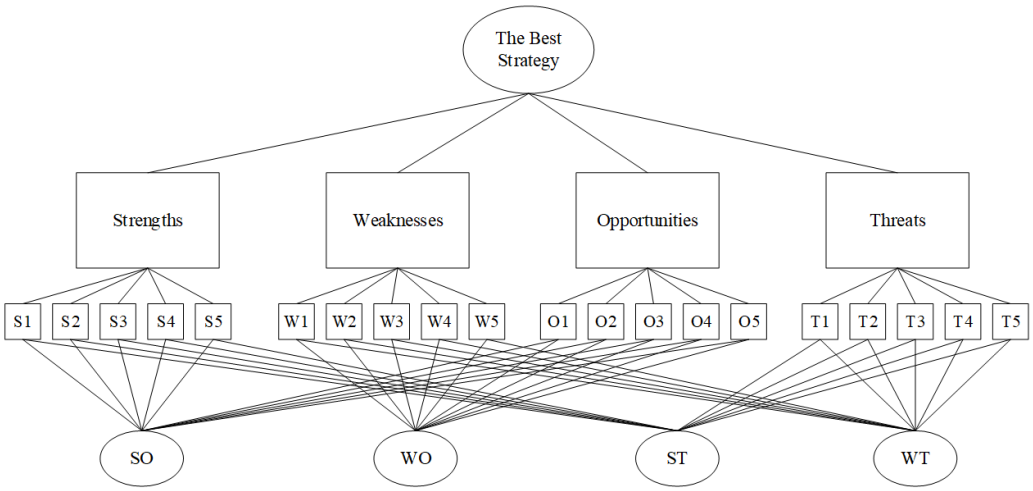

Figure 5. AHP model for the selection of the best strategy

Note: This figure was prepared by the authors.

To be able to apply the AHP method for the final evaluation of SWOT elements and their transformation into TOWS strategic directions, a pool of experts was developed, consisting of 6 experts from all six institutions of the project consortium, including one expert from Poland, the Czech Republic, Slovakia, Hungary, Bulgaria, and Serbia. Experts were asked to evaluate and pairwise rank the SWOT groups. The obtained pairwise rank is presented in Table 2.

Table 2. Pairwise comparison of the SWOT groups

SWOT Groups	S	W	O	T
S	1	4	1/2	3
W	1/4	1	1/7	2
O	2	7	1	5
T	1/3	1/2	1/5	1

Table 3. Pairwise comparison of the SWOT sub-criteria – Strengths

Strengths (S)	S1	S2	S3	S4	S5
S1 - adequate supply chain	1	1/4	5/4	1/4	5
S2 - availability of necessary raw materials	4	1	5	3	7
S3 - Large foreign companies are looking for local subcontractors	4/5	1/5	1	1/4	5
S4 - flexibility and ability to adapt to market needs	4	1/3	4	1	6
S5 - stable growth of the SME sector	1/5	1/7	1/5	1/6	1

Table 4. Pairwise comparison of the SWOT sub-criteria – Weaknesses

Weaknesses (W)	W1	W2	W3	W4	W5
W1 - insufficient financial resources for growth	1	1/6	1/2	1/6	1/6
W2 - obsolete equipment	6	1	5	1/4	1/3
W3 - high administrative requirements for SMEs	2	1/5	1	1/5	1/5
W4 - lack of capital and limited access to funds	6	4	5	1	3
W5 - lack of human resources	6	3	5	1/3	1

Table 5. Pairwise comparison of the SWOT sub-criteria – Opportunities

Opportunities (O)	O1	O2	O3	O4	O5
O1 - development of a new industrial zone in the region	1	5	3	4/5	5/6
O2 - external support (support from the state and foreign investors)	1/5	1	1/4	3	1/6
O3 - the end of the COVID pandemic	1/3	4	1	5	1/4
O4 - growing demand for healthy products	5/4	1/3	1/5	1	1/7
O5 - EU programmes and funds for the development of the SME sector	6/5	6	4	7	1

Table 6. Pairwise comparison of the SWOT sub-criteria – Threats

Threats (T)	T1	T2	T3	T4	T5
T1 - increasing production costs	1	4	5	6	3
T2 - lack of necessary resources	1/4	1	3	4	1/3
T3 - the coming recession that is just beginning	1/5	1/3	1	3	1/4
T4 - deteriorated natural conditions	1/6	1/4	1/3	1	1/5
T5 - continuous changes in the legal framework of business	1/3	3	4	5	1

Table 7. The importance of the criteria and sub-criteria of the SWOT analysis

SWOT Groups Criterions	Importance of the SWOT Criterions	SWOT Sub-Criterions	Local Importance of the SWOT Sub-Criterions	The Global Importance of the SWOT SubCriterions
Strengths - S	0.29	S1 - adequate supply chain	0.12	0.034342882
		S2 - availability of necessary raw materials	0.46	0.130907485
		S3 - large foreign companies are looking for local subcontractors	0.11	0.030468178
		S4-flexibility and ability to adapt to market needs	0.28	0.079256946
		S5 - stable growth of the SME sector	0.04	0.010803226
Weaknesses - W	0.10	W1 - insufficient financial resources for growth	0.04	0.004475066
		W2 - obsolete equipment	0.18	0.018560963
		W3 - high administrative requirements for SMEs	0.06	0.006645212
		W4 - lack of capital and limited access to funds	0.44	0.045368735
		W5-lack of human resources	0.27	0.027226275
Opportunities - O	0.53	O1 - development of a new industrial zone in the region	0.27	0.142282177
		O2 - external support (support from the state and foreign investors)	0.08	0.039999406
		O 3 - the end of the COVID pandemic	0.22	0.115873751
		O4 - growing demand for healthy products	0.05	0.026304844
		O5 - EU programmes and funds for the development of the SME sector	0.39	0.204369984
Threats - T	0.08	T1 - increasing production costs	0.46	0.038179765
		T2 - lack of necessary resources	0.15	0.012465946
		T3 - the coming recession that is just beginning	0.09	0.007090672
		T4 - deteriorated natural conditions	0.05	0.003890436
		T5 - continuous changes in the legal framework of business	0.26	0.021488051

In the following step, the local importance of SWOT sub-criteria was determined by the same expert team, while the scores of comparative pairs of SWOT sub-criteria, defined in Table 2, are given in Table 3, Table 4, Table 5, Table 6.

Subsequently, normalization, local criterion importance, and degree of consistency were calculated for all four criteria (S, W, O, and T). The same calculations were also performed for all identified sub-criteria (S1-S5, W1-W5, O1-O5, T1-T5). For each of the SWOT factors, the degree of consistency was calculated, which equaled 0.0505,

0.095, 0.095, and 0.07 for Strengths, Weaknesses, Opportunities and Threats, respectively. Through AHP method calculations, the global importance of SWOT sub-criteria is calculated, as presented in Table 7. The applied AHP procedure resulted in the TOWS matrix, given in Table 8.

Table 8. SWOT - TOWS matrix with resulting strategic alternatives defined

	Internal Factors	
	S1 - adequate supply chain **S2 - availability of necessary raw materials** S3 - large foreign companies are looking for local subcontractors S4 - flexibility and ability to adapt to market needs S5 - stable growth of the SME sector	W1 - insufficient financial resources for growth W2 - obsolete equipment W3 - high administrative requirements for SMEs W4 - lack of capital and limited access to funds **W5 - lack of human resources**
External Factors		
O1 - development of a new industrial zone in the region O2 - external support (support from the state and foreign investors) O3 - the end of the COVID pandemic O4 - growing demand for healthy products **O5 - EU programmes and funds for the development of the SME sector**	SO1: Develop a differentiation strategy based on available EU programmes and funds for the development of SMEs - taking into account the availability of necessary raw materials	WO1: Compensate the observed lack of human resources with the possibilities of increased digitization and the application of the Industry 4.0 concept, with the intensive use of available EU funds for the development of the SME sector
T1 - increasing production costs T2 - lack of necessary resources T3 - the coming recession that is just beginning T4 - deteriorated natural conditions T5 - continuous changes in the legal framework of business	ST1: A strategy of compensating for rising production costs by using a wide range of available resources and an adequate selection of the raw material base	WT1: To be maximally committed to the motivation of employees to remain loyal to their companies and regardless of the increase in production costs, not to think in the direction of reducing wages in the sector

When looking at the rankings of the SWOT groups presented in Table 7, it is obvious that the most important opportunities with a significance coefficient of 0.53 are followed by strengths with 0.29, then weaknesses with 0.10, and finally threats with 0.08. This ranking points out that the experts who evaluated these groups are more in favor of development strategies that will be based on the opportunities and strengths of the organization.

When looking at the overall significance of the sub-criteria, the most significant determinant is "O5-EU programmers and funds for the development of the SME sector" (with a coefficient of 0.204369984). Followed by "S2 - availability of necessary raw materials" (0.130907485), "T1 - increasing production costs" (0.038179765) and finally "W5 - lack of human resources" (0.027226275).

The result of the ranking represents the basis for further development of the TOWS matrix in order to define strategic actions, as shown in Table 8.

Based on the above ranking, the following strategic actions could be proposed:

SO1: Develop a differentiation strategy based on available EU programs and funds for the development of SMEs, taking into account the availability of necessary raw materials.

ST1: Strategy to compensate for rising production costs by using a wide range of available resources and an adequate selection of the raw material base;

WO1: Compensate the perceived lack of human resources with the possibilities of increased digitization and application of the Industry 4.0 concept, with intensive use of available EU funds for the development of the SME sector;

WT1: Maximize the motivation of employees to remain loyal to their companies, and regardless of the increase in production costs, do not think in the direction of reducing wages in the sector.

The order of application of strategies should be implemented in the specified order: SO1 $\rightarrow$ ST1 $\rightarrow$ WO1 $\rightarrow$ WT1, bearing in mind the importance of the assessed groups of the SWOT analysis. This way the hierarchy of the strategic actions was obtained, based on the collected SWOT factors, decision-makers filtering and rating of the SWOT factors, and subsequent MCDA ranking of the alternatives. Based on the research presented in this manuscript,

it can be concluded that strategic actions in the case of observed manufacturing SMEs should be directed towards the development of a differentiation strategy based on available EU programs and funds, taking into account the availability of necessary raw materials. This strategic direction should be followed by the strategy to compensate for rising production costs by using a wide range of available resources and an adequate selection of the raw material base. Subsequently, the strategic direction should be to compensate for the perceived lack of human resources with the possibilities of increased digitization and application of the Industry 4.0 concept, with intensive use of available EU funds. At the end, the strategic direction should be to maximize the motivation of employees to remain loyal to their companies, and regardless of the increase in production costs, do not think in the direction of reducing wages in the sector. Off course, these strategic directions were defined based on the survey results collected during the described project activities. Considering that, in the meantime, the conditions on the market may have changed, running the new phase of application usage in the same region could result in different strategic directions. This is an additional advantage of this tool. Namely, once collected results in the database remain there and can be used for comparison with the new SWOT factor ratings, which will result from the next phases of the application use.

4 Conclusions

SMEs, as strongly innovative and heterogeneous organizations, especially if operating in the digital fabrication industrial sectors, should aim to mitigate bias and subjectivity in SWOT analysis by involving diverse approaches and seeking external perspectives [44]. SWOT/TOWS analysis, based on the software application developed in this research and described in this paper, offers a more systematic approach to strategy development and is particularly beneficial for SMEs looking to balance their strengths and weaknesses effectively.

Upgrading the SWOT tool with the quantified TOWS-AHP method enables decision-makers to materialize their selection of SWOT elements in the form of practical strategic alternatives and choose the most appropriate strategic directions.

As indicated by Vlados [43], SWOT analysis is usually a one-time event; thus, in its native form, it is without a proper mechanism to monitor changes throughout a long-term dynamic competitive situation. The approach described in this research enables conducting the SWOT analysis from a dynamic perspective using the app tool described. Namely, once the application is installed on the decision-makers' computer, there is no limit to the number of his/her co-workers invited to do the SWOT evaluation of the organization. All obtained results are collected in the central database and updated with each single response, enabling the dynamic tracking of the obtained average values of rated SWOT factors. This can be stated as the most important contribution of the research presented in this manuscript. Besides being a potentially practical tool for SMEs owners and entrepreneurs, the software application described is also used for educational purposes on the master-level course as part of the case studies in strategic decision-making.

Of course, the research presented in this manuscript also has some identified limitations. The first limitation is the fact that the pilot testing of the application was conducted with a limited number of 63 decision-makers. In the further development of the commercial version of the application, the testing will be expanded with a larger number of organizations involved. Also, the explained methodology has one point where the subjective decisions of the pool of experts can come to light (Stage III in Figure 1). Namely, the AHP methodology described is not completely integrated in this application automatically. In the present form of the application, there was a requirement to send the best-ranked SWOT factors to the pool of six experts, who were selected among the professors of the project consortium institutions. The experts conducted the pairwise comparison and ranking of the selected SWOT factors, and such obtained results were then used for the AHP module calculations. This, of course, resulted in some subjectivity of the process. In future development of the application, additional add-ins will be included that will be based on the opportunity for the decision-maker to rate the importance of each of the SWOT factors. This way, the decision-makers will enter their ratings of the present values of proposed factors in their organizations, as well as their importance. This will enable the calculation of the importance of the TOWS strategic alternatives without relying on the subjective opinions of the pool of experts. This, of course, will be the direction of further research on the topic.

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Data Availability

The application presented in this manuscript was developed using the Python programming language, and the beta version is publicly available for download at the following link: https://machinery.mas.bg.ac.rs/bitstream/handle/123456789/5499/SWOT%20APP.rar?sequence=1&isAllowed=y.

Conflicts of Interest

The authors declare no conflict of interest.

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